

# In-patient physiotherapy for adults on veno-venous extracorporeal membrane oxygenation – United Kingdom ECMO Physiotherapy Network: A consensus agreement for best practice

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## Abstract

Clinical specialist physiotherapists from the five severe respiratory failure centres in England where respiratory extra-corporeal membrane oxygenation (ECMO) is practiced have established this consensus agreement for physiotherapy best practice. The severe respiratory failure centres are Wythenshawe Hospital, Manchester; Glenfield Hospital, Leicester; Papworth Hospital, Cambridge; Guy's and St Thomas' Hospital, London and The Royal Brompton Hospital, London. Although research into physiotherapy and ECMO is increasing, there is not a sufficient amount to write evidence-based guidelines; hence the development of a consensus document, using knowledge and experience of the specialist physiotherapists working with patients receiving ECMO. The document outlines safety aspects, practicalities and additional treatment considerations for physiotherapists conducting respiratory care and physical rehabilitation.

## Keywords

Extracorporeal membrane oxygenation, rehabilitation, respiratory therapy, intensive care, physical therapy

## Introduction

Veno-venous extracorporeal membrane oxygenation (VV ECMO) support for patients with severe respiratory failure is commissioned by NHS England at five Trusts in England. The service manages patients throughout England and the wider United Kingdom (UK) if they have acute severe respiratory failure with an underlying reversible cause and a Murray score of 3 or more. The Murray score is used to characterise the severity of lung injury, scored on a range from 0 to 4 in each category, which are: number of quadrants with consolidation on chest X-ray, hypoxaemia ( $\text{PaO}_2/\text{FiO}_2$ ), positive end expiratory pressure (PEEP) and lung compliance.<sup>1</sup> Patients are retrieved from other hospitals to the regional centre, either on conventional ventilation or on mobile ECMO and remain under the care of the ECMO specialist service for 48 h (or until stable) following decannulation from ECMO. Patients are subsequently repatriated to their

referring hospitals, though the timing varies between patients and centres.<sup>2</sup>

Whilst at the specialist severe respiratory failure centre for ECMO, patients may receive respiratory and rehabilitative physiotherapy. Whilst the provision of physiotherapy service is variable within the UK and worldwide, evidence supporting physiotherapy and ECMO is increasing,<sup>3,4</sup> as is the awareness of the importance of physiotherapy and rehabilitation within ICU.<sup>5</sup> Respiratory physiotherapy can reduce ventilator-associated pneumonia, improve static lung

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compliance, enhance sputum clearance and address atelectasis and lobar collapse.<sup>6-9</sup> However, it should be noted that these studies are not based on patients on ECMO. The timing of these treatments depends on the stage of acute respiratory distress syndrome (ARDS) and clinical indication. The evidence regarding respiratory physiotherapy during VV ECMO is limited to two case studies describing the use of ventilator hyperinflation and manual techniques in an ECMO patient with ultra-protective lung ventilation.<sup>3,10,11</sup> There are also single centre studies reviewing the treatment options used in respiratory physiotherapy which highlights the variability between ECMO centres as to how respiratory physiotherapy is provided to ECMO patients.<sup>12,13</sup>

Rehabilitation on ICU has been shown to be safe and that early intervention results in decreased episodes of delirium, decreased duration of mechanical ventilation, decreased ICU and hospital lengths of stay, improved functional ability and improved mortality.<sup>14-18</sup> The growing use of ECMO for patients with severe respiratory failure raises challenges for physiotherapy and rehabilitation.<sup>19</sup> The ECMO patient cohort is a particularly difficult group with a mixed aetiology of respiratory failure including pre/post lung transplant, trauma and pneumonia. Historically, patients on ECMO are heavily sedated with prolonged bed rest, and exposure to muscle relaxants and corticosteroids, which puts them at high risk of physical disability. In addition to this, attachments such as ECMO cannulae may limit treatment options, dependent on insertion location. Despite this, it seems reasonable that the benefits of early rehabilitation seen in the general ICU population apply to patients receiving ECMO. However, it should be noted that even with early rehabilitation, patient who survive ARDS and those who survive ARDS with ECMO support have a reduced health related quality of life at a one-year follow-up.<sup>20-21</sup> There is an increasing number of patients awake on ECMO, therefore reducing the negative effects of sedation.<sup>3,22</sup> This expedites the ability to participate in rehabilitation and liberation from ventilation, however the effect of increased work of breathing and patient anxiety needs to be considered.<sup>23-25</sup>

National care standards for rehabilitation within ICU are relevant and should be applied to patients receiving ECMO. Therefore, these patients should receive assessment for risk of physical and non-physical morbidity, assessment of rehabilitation needs within 24h of admission, active therapy to enable them to achieve their goals, and the use of outcome measures.<sup>26-28</sup> Rehabilitation on ECMO requires a careful, multi-disciplinary approach, including involvement of staff with experience of moving patients on ECMO.<sup>3,4,22</sup>

### *ECMO multi-disciplinary team*

The ECMO team consists of senior staff from different specialities to provide input into operational planning, service development, peer review and specialist clinical support. The core team will differ between centres, but usually consists of:

- Intensive care consultant/ ECMO consultant
- ECMO co-ordinator
- ECMO trained specialist nurse
- Perfusionist
- Senior nurse in charge
- Senior ICU specialist physiotherapist

### *Key consideration for safety during treatment*

Patients on ECMO have one or more large cannulae in central veins (femoral or jugular) to allow the continuous flow of up to 6L/min of blood per cannulae through the ECMO circuit. A disturbance to that flow or episode of unplanned decannulation is potentially life-threatening due to the risk of severe hypoxaemia.<sup>3</sup> Studies report mobilising patients receiving ECMO as a bridge to lung transplant or bridge to recovery. These studies have involved small patient numbers, however this process appears to be safe and show good functional outcome for patients.<sup>29-33</sup> A systematic review of nine reports and 52 patients in total also found that although considered a high-risk procedure, passive and active physiotherapy was safe when undertaken with a highly specialised team.<sup>3</sup> There have been no reported significant adverse events during rehabilitation on ECMO, however it should be acknowledged that these reports are from highly expert teams.

There are currently no national established guidelines or protocols for mobilising patients on ECMO, therefore practice regarding mobilisation and rehabilitation is likely to vary widely between institutions. There are also no national established guidelines or protocols for respiratory physiotherapy treatment for patients on ECMO. Given the relative lack of evidence, the severe respiratory failure centres who provide ECMO in England have formed a specialist physiotherapy group to provide expert consensus and recommendations for the physiotherapy treatment of VV ECMO patients within the ICU. The group present key recommendations within this document, but at present, evidence is lacking to provide standards of care.

*Preparation for physiotherapy.* Refer Figure 1.

## Physical rehabilitation

### Recommendations

Early, regular and ongoing rehabilitation is suitable and recommended for patients receiving VV ECMO

Rehabilitation should progress in line with patients ability; ranging from passive exercise, to getting out of bed, and walking

To ensure patient safety at all times:

- Appropriate pre-treatment checks should be performed
- The appropriate level and skill mix of staff should be present
- Recognition that any member of the team has the authority to stop progression of the session if any concerns are identified

Rationale for rehabilitation:

- Prevention of bed rest-related problems
- Optimise early recovery
- Improve functional ability as quickly as possible
- Improve mood and psychology with engagement in goal setting and attainment

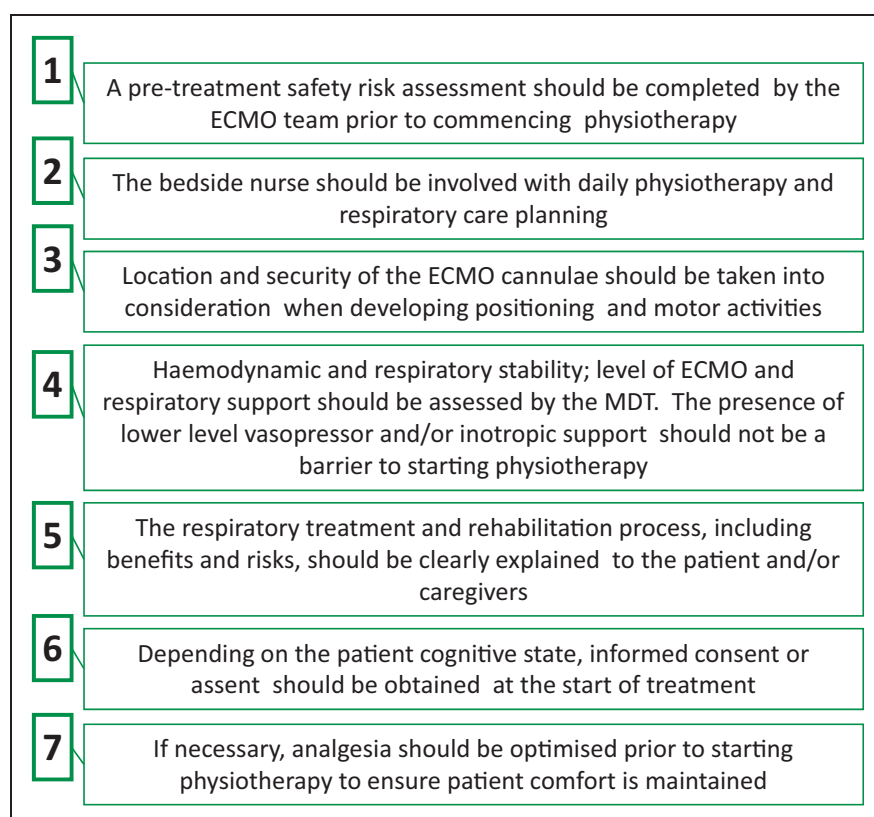
## Pre-treatment safety

## Patient monitoring

- The patient should be connected to vital signs monitoring throughout the rehabilitation session. The level of monitoring required, including parameters, will be agreed at an institutional level by the ECMO team taking into consideration the individual patient.
- Baseline observations should be observed and documented prior to commencing exercise.
- Any changes in blood pressure, heart rate, peripheral haemoglobin oxygen saturation or ECMO flows should be noted and responded to appropriately. The rehabilitation session should be terminated and the patient returned to bed if there is an adverse change in observations that do not respond to basic intervention such as an increase in FiO<sub>2</sub>.
- Patients may require additional mechanical ventilation or ECMO support to perform rehabilitation due to increased cardiac output, oxygen consumption and carbon dioxide production during the physical activity.
  - Patients with minimal native lung function (for example; tidal volumes <200 mL, or no change in PaO<sub>2</sub> with an increase in Fio<sub>2</sub> to 1.0 for 30 min to assess contribution of lungs to gas exchange) may require increased ECMO blood flow during the rehabilitation activity.
  - Patients with recovering lung function (for example; tidal volumes >200 mL and incremental change in PaO<sub>2</sub> following increase in Fio<sub>2</sub> to 1.0) may require increased FiO<sub>2</sub> via the

**Table 1.** Pre-treatment safety issues on VV ECMO patients.

Safety	<ul style="list-style-type: none"> <li>- Safety is paramount throughout the physiotherapy session.</li> <li>- It is recommended that a written risk assessment is completed prior to undertaking physiotherapy, particularly for mobilisation.</li> <li>- A team brief including all team members taking part in the rehabilitation session should occur prior to commencing activity to ensure that each team member understands their role and the sequence of events planned.</li> <li>- It is recommended that a pre-assessment checklist is completed on each review prior to commencing physiotherapy.</li> <li>- It is the physiotherapist's responsibility to confirm checks before commencing physiotherapy.</li> <li>- An ECMO trained professional should be also present with the physiotherapist throughout the treatment session.</li> <li>- An appropriate number, skill mix and level of the experience of staff should be also throughout the treatment.</li> </ul>
Infusions and pharmacological status	<ul style="list-style-type: none"> <li>- Inotropic and vasopressor support should not exclude patients from physiotherapy. However, if high doses are required by the patient with persistent cardiovascular instability, physiotherapy may not be possible. This should be discussed with the ECMO consultant responsible for the patient's care.</li> <li>- Anti-coagulation should be within the limits set by the ECMO consultant for the day prior to commencing physiotherapy</li> </ul>
Cannulae	<ul style="list-style-type: none"> <li>- The internal position of the cannulae should be radiographically confirmed.</li> <li>- The ECMO cannulae should be secured safely in compliance with each centre's local procedure. In addition to physical support by the ECMO specialist, the use of headband/endotracheal tube tapes and dermal dressing may be used.</li> <li>- Prior to commencing physiotherapy, the ECMO cannulae should be deemed secure by a suitably trained ECMO nurse</li> </ul>



**Figure 1.** Preparation for physiotherapy: seven steps flow chart.

ventilator and/or increased ECMO blood flow during the rehabilitation activity. Fluid boluses may be required to avoid complications related to changes to ECMO flow settings.

- Any and all changes to ECMO support required during rehabilitation should be performed by a qualified ECMO specialist.
- Patients should be monitored after exercise has finished for any delayed adverse response to exercise.
- During treatment, staff should be conscious of the risk of bleeding from cannulation sites, movement of cannulae and reduction in blood flow due to position changes. If patients complain of pain on movement following the removal of cannulae the site should be investigated as a haematoma may be present around the insertion point.

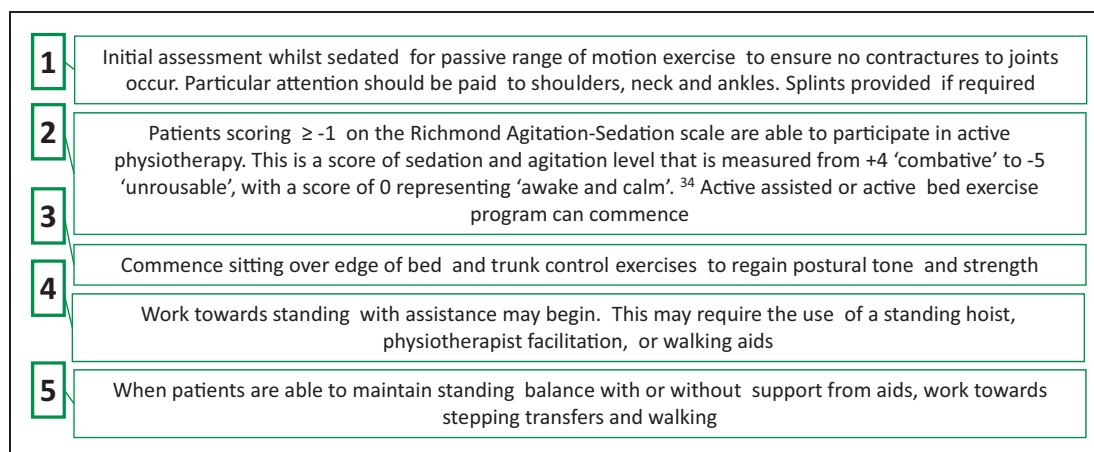
### *Roles and responsibilities*

Minimum staffing:

- At least two members of the physiotherapy team for rehabilitation session involving moving the patient. The lead physiotherapist should be senior, with ECMO rehabilitation experience and competence. The appropriate number of physiotherapy staff and skill mix may change dependent on the rehabilitation task planned.

- ECMO specialist nurse; perfusionist or duty ECMO coordinator for ECMO cannulae safety.
- Suitably trained staff for other lines and airway management.

- Additional members of staff may be required if the patient require more assistance with moving and handling or to monitor lines and equipment.
- Medical staff; ECMO specialist nurse; duty ECMO consultant or duty ECMO co-ordinator will be responsible for securing the ECMO cannulae prior to commencing rehabilitation. Adequate length of tubing to allow movement must be assessed prior to movement. They will also be responsible for monitoring the cannulae throughout the rehabilitation session and securing them on movement.
- The physiotherapists will be responsible for leading the rehabilitation session ensuring patient safety throughout the session.
- The therapy team involved must be deemed competent by the ICU physiotherapy lead according to locally agreed competencies and criteria.
- Suitably competent nursing staff or perfusionists will be responsible for monitoring ECMO flows and the circuit throughout the session and assisting with rehabilitation as required.
- The patient's airway, observations and response to the treatment session will be monitored throughout



**Figure 2.** VV ECMO rehabilitation protocol: five steps flow chart.

the session with all team members being aware of alarms and airway safety.

- Any member of the team has the responsibility and authority to stop progression of the session if any concerns are identified.
- In the event of an adverse incident occurring during physiotherapy, if it is not possible to return the patient safely to bed, they should be safely lowered to the floor to allow any emergency care to be provided. Appropriate incident reporting should be completed in the event of an adverse incident.

### Rehabilitation protocol

The following illustration provides a suggested progression for rehabilitation with patients who are awake on VV ECMO (Figure 2).

Throughout this process, patient progress will be continually monitored and treatment sessions adapted accordingly. If there are periods of medical instability during the rehabilitation phase it may be necessary to halt rehabilitation sessions for a period of time, or to return to earlier stages of the rehabilitation pathway as required.

### Rehabilitation treatment options and equipment

In addition to rehabilitation treatment techniques' outlines above (limb exercises, sitting over edge of bed, standing, and stepping transfers) other rehabilitation techniques and equipment can be used.

- Rehabilitation equipment for moving and handling safety for both patients and staff should be used as appropriate, e.g. standing frames, zimmer frames, tilt table.
- For more debilitated patients with poor lower limb function, a bed bike can be used, with progression onto chair pedals for patients able to sit out of bed. The bed and chair pedals treatment modalities can be passive, or involve active participation and can

be used as an adjunct for specific lower limbs muscle strengthen and general range of movement.

- If patients are able to sit out of bed, a chair with an appropriate level of support for the patient's trunk strength and pressure care needs must be provided. Appropriate seating must be used to allow reclining, or patient transfer board/hoisting back to bed in an emergency.
- For physically able patients, upright cycle and walking around ICU is possible with appropriately trained staff.

### Assessing outcome

- In adherence with D16 standards<sup>27</sup> and NICE guidance CG83<sup>28</sup> a short clinical assessment should be undertaken on admission to identify patients at risk of physical and non-physical morbidity. A comprehensive clinical assessment should then be performed on admission and before discharge.
- Once patients commence rehabilitation, appropriate goals should be set with patients and their family in order to target therapy to the individual. These goals can then be used to assess achievement of rehabilitation targets.
- Patient's progress and response to rehabilitation should be regularly assessed by a qualified practitioner; this is often the physiotherapist. Progress should be assessed at least weekly, but more often if the patient's status changes significantly.
- Using a multi-disciplinary approach, patients should be assessed using a validated rehabilitation outcome measure on commencement of rehabilitation and discharge from the ICU.<sup>26</sup> The following are used within the UK ECMO centres: The Chelsea Critical Care Physical Assessment Tool,<sup>35</sup> Functional Independence Measure/Functional Assessment Measure,<sup>36</sup> Physical Function ICU Test<sup>37</sup> and Manchester mobility score.<sup>38</sup> Variability exists with the use of outcome measures,



as at present there is not a 'gold standard' outcome measure to assess physical ability within ICU.<sup>39</sup>

- The rehabilitation plan and outcome measure should be provided as part of the handover to other hospitals following repatriation or on ward transfer.

### Other therapy input

Involvement of occupational therapy, speech and language therapy, psychological support and dieticians should be considered early, dependent on resources within the centre. Post discharge support from ECMO follow-up clinics is also required to address physical impairment, psychological stress and emotional support for the patient and their families and carers.<sup>40</sup>

## Respiratory treatment

### Recommendations

- Patients on VV ECMO require respiratory assessment and intervention from physiotherapy
- Treatment aims should include sputum clearance and improving lung volume

Rationale for respiratory treatment:

- To optimise clearance of secretions from airways
- Improve ventilation in the presence of atelectasis/collapse
- Maximise ventilation/perfusion potential

Dependent on local policy ECMO patients may be assessed for respiratory treatment on admission or on referral. If assessment is required, this should be performed by a suitably qualified physiotherapist in a timely fashion. Local protocol and clinical need will dictate frequency of further intervention. The majority of ECMO patients will be ventilated; however, some may be self-ventilating via a tracheostomy or without an artificial airway.

### Prior to respiratory treatment

A full respiratory assessment should be conducted, this should include: ECMO settings, ventilation mode, flow curves and compliance, arterial blood gases, oxygenation saturation, auscultation, observation and palpation of the chest wall movement and fremitus, review of chest X-ray or CT scan. In cases of significantly reduced tidal volumes due to ultra-protective ventilation or poor compliance some assessment techniques will be of limited use, however this will become more useful with lung recovery and an increase in lung volume.

In addition to a respiratory assessment and review of the preparation for physiotherapy flow chart (Figure 1) the following should also be considered in more depth:

- Assessment of lung compliance should be performed if appropriate for patients who are ventilated. Lung compliance is often calculated by the ventilator and can be read off the monitor screen, or calculated using the following formulas:

- Dynamic compliance:

$$\frac{\text{Exhaled tidal volume}}{\text{cm H}_2\text{O peak inspiration pressure} - \text{PEEP}}$$

- Static compliance:

$$\frac{\text{Exhaled tidal volume}}{\text{cm H}_2\text{O plateau pressure} - \text{PEEP}}$$

- Recent radiological imaging should be reviewed prior to treatment to assess for changes within the lung fields and position of the ECMO cannulae.
- The level of sedation/ neuromuscular blocking agents should be considered as part of the assessment/ treatment planning.
- Locally agreed respiratory personal protective equipment precautions should be adhered to during respiratory treatment due to the generation of aerosolised particles.

## Safety

Safety considerations are outlined in Table 1.

### Respiratory treatment options

The full range of treatment options should be considered for ECMO patients requiring respiratory intervention. However, additional consideration may be required due to cannulation sites, lung pathology, stage of lung recovery and compliance, anti-coagulation level and effect on ECMO flows.

Before breaking the ventilator circuit or aerosolising respiratory generated particles consider the risks to the patient and staff, and use infection control precautions required.

Please refer to Table 2 for precautions and recommendations for respiratory interventions.

## Keypoints

- Physiotherapist should be involved with patients receiving ECMO from admission: for assessment, respiratory treatment and rehabilitation treatment.

**Table 2.** Precautions and recommendations for respiratory interventions on VV ECMO patients.

Intervention	Precautions	Management/Recommendations
Positioning	Position of cannulae, risk of VQ mismatch, patient stability	Positions discussed with ECMO consultant and specialist nurse
Saline	Derecruitment	Instill via closed suction port
Suction	Airway bleeding and derecruitment	Closed suction, monitoring of platelet level, ACT/APTT ratio
VHI and MHI	Maximum peak pressures should be agreed by ECMO MDT. Consider lung compliance and may not be appropriate if on ultra-protective ventilation (e.g. barotrauma) May not be appropriate with inadequate/unstable ECMO flows. In MHI a manometer should be used to a locally agreed pressure Avoid MHI if PEEP levels are >10 cm H <sub>2</sub> O, VHI should be considered	Review lung compliance before commencing treatment Use VHI in patients with high PEEP or use PEEP valve in MHI circuit
Mechanical insufflation: Exsufflation	Consider lung volume and compliance Risk of over distention and derecruitment	Review lung compliance before commencing treatment
Manual techniques	Consider cannulae position within vessels May not be appropriate with inadequate/unstable ECMO flows	Commence gentle manual techniques
Nebulisers	Consider appropriateness of breaking circuit and tidal volume for effectiveness of distribution	Discuss with ECMO consultant and specialist nurse Use in circuit nebuliser system
Physiotherapy-assisted flexible bronchoscopy	May not be appropriate with inadequate/unstable ECMO flows	Liaise with ECMO consultant or ICU consultant performing FOB
HFCWO	Arrhythmias, clotting, position of cannulae, wounds	Discuss with ECMO consultant and specialist nurse
Autogenic drainage/ACBT	Consider effect of raising intrathoracic pressure during treatment	Amend treatment plan if adverse changes to cardiovascular system
PEP	Consider lung volumes	Review lung compliance before commencing PEP
IPPB	Consider lung compliance	Review lung compliance before commencing IPPB
Nebulised DNase	Airway bleeding	Discuss with ECMO consultant and specialist nurse

VQ: ventilation-perfusion; ACT/APTT: activated clotting time/activated partial thromboplastin time; VHI: ventilator hyperinflation; MHI: manual hyperinflation; MDT: multi-disciplinary team; PEEP: positive end-expiratory pressure; ICU: intensive care unit; FOB: fiberoptic bronchoscopy; HFCWO: high frequency chest wall oscillation; ACBT: active cycle of breathing techniques; PEP: positive expiratory pressure; IPPB: intermittent positive pressure breathing; DNase: deoxyribonuclease.

- The likelihood of adverse events during treatment can be reduced by using a highly specialised team with each team member assigned specific roles.
- Safety during treatment is paramount; safety checks pre, during and post treatment are essential.
- Current evidence supports rehabilitation in awake patients on VV ECMO. There is limited evidence on respiratory intervention.

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### Ethics

This consensus document has been approved and endorsed by the Association of Chartered Physiotherapists in

Respiratory Care (ACPRC) committee.



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